HEAVY METALS CONCENTRATIONS IN RIVERS CHANCHAGA AND LAPAI GWARI, MINNA, NIGER STATE, NIGERIA

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ABSTRACT

This study assessed the concentrations of heavy metals in Rivers Chanchaga (upstream) and Lapai Gwari (downstream), Minna, Niger State, Nigeria. Over three months (July to September 2019), water samples were collected and temperature, dissolved oxygen, biochemical oxygen demand (BOD) and pH were measured. In addition, heavy metals such as Manganese (Mn), Copper (Cu), Lead (Pb) and Iron (Fe), were assessed. Temperature exhibited monthly variations, ranging from 24.4°C in August to 26.0°C in September. Dissolved oxygen levels varied from 4.12 mg/L (August) to 6.50 mg/L (July), while BOD increased from 0.88 mg/L to 1.88 mg/L. The pH was highest in August (8.97) and least in July (6.87). Lead (0.02 mg/L - 1.60 mg/L), Mn (0.07 mg/L - 0.24 mg/L), and Fe (0.08 mg/L - 0.36 mg/L) were in significant amounts in July, while Cu varied from 0.03 mg/L to 0.21 mg/L in September. The study identified industrial, urban, domestic, and agricultural sources as major contributors to water contamination in Rivers Chanchaga and Lapai Gwari. Effective management and mitigation measures are imperative to protect these vital water resources.

Keywords: Heavy metals, River Chanchaga, River Lapai Gwari, Physicochemical parameters, Water quality

INTRODUCTION

Water is one of the most essential natural resources required for sustenance of all life forms (Vanloon and Duffy, 2005; Enyoh *et al.*, 2018; Enyoh *et al.*, 2022). Water quality assessment provides information on the concentration of solutes, physiochemical characteristics and health of aquatic ecosystems (Venkatesharaju *et al.*, 2010; Batagarawa and Lawal, 2019; Sadiq *et al.*, 2022). The survival and growth of aquatic organisms, are greatly influenced by variations among water quality parameters. These influence reproduction and could lead to migration of some species (Bhatnagar and Devi, 2013). Simpi *et al.* (2011) emphasized the significance of a thorough understanding of the hydro-biological processes that result from metabolic processes in aquatic ecosystems. Natural water typically contains pollutants that come from anthropogenic (mining, processing, agricultural operations and oil spills) and natural sources (rock weathering, leaching from soils, and dissolved particles of aerosols) (Adeyeye, 1994; Ugbaja and Ephraim, 2018).

Unfortunately, rapid growth in population and industrial activities are negatively impacting water quality in the state (Ogungbile *et al.*, 2023). Wastewater discharge is a prominent pathway through which heavy metals, such as copper (Cu), lead (Pb), and cadmium (Cd), enter soil and aquatic systems, with irrigation being a notable route (Khan *et al.*, 2008; Enyoh, 2018). Heavy metals are metallic compounds with a relatively high density and are deadly or hazardous at low doses (Adedeji and Okocha, 2011). They cause indirect toxicity through their bioaccumulation in the aquatic food web (Al-Weher, 2008; Odu *et al.*, 2011; Medjor *et al.*, 2012; Smiljanic *et al.*, 2019; Balali-Mood, 2021).

In the rural areas of Niger State, rivers are used for artisanal fishing, bathing and other domestic purposes (drinking). Abubakar *et al.* (2020) highlighted that industrial waste, agricultural runoffs, municipal waste and accidental spills are the four primary causes of water pollution. The poisonous metals from different home and industrial sources are often dumped in landfills and are sometimes dumped into bodies of water (Arif-Reza and Yousouf, 2016; Lin *et al.*, 2022). Chanchaga River, as it traverses through the Minna metropolis, is polluted due to the dumping of domestic and agricultural waste, including heavy metals. Downstream from Chanchaga River lies the Lapai Gwari River, which is integral to the same interconnected aquatic system. Although these two rivers might seem geographically separate, they are part of a broader network, and the health of one river significantly affects the other. These rivers serve multiple vital purposes, including irrigation, household usage, and aquaculture.

This study assessed the concentrations of Manganese (Mn), Iron (Fe), Copper (Cu), and Lead (Pb) in River Chanchaga (upstream) and River Lapai Gwari (downstream) in Minna, Niger State, Nigeria. Physico-chemical parameters such as temperature, pH, dissolved oxygen, and biochemical oxygen demand (BOD) were also assessed.

MATERIALS AND METHODS

Study Area

Data were collected from the upstream segment of River Chanchaga in Chanchaga LGA and downstream segment of River Lapai Gwari in Bosso LGA, Niger State, Nigeria. Chanchaga local government area lies between latitude 9° 32' 24"N and longitude 6° 34' 48"E, with its headquarters in Minna (Figure 1). It has a total population of 201,429. River Chanchaga flows through Kasobo, Numu Kpan, Tunga-Waya, Isafi-Wambai Gurusa and Chanchaga communities. Bosso LGA lies between latitude 9° 31′ N and longitude 6° 31′ E with its headquarters in Maikunkele. It has a population of 208,212. The local residents are predominantly farmers. Domestic wastes are dumped in the rivers and activities such as bathing, washing, sand mining and fishing are done on the banks of the rivers. There were five sampling locations at each river (Figure 1).

Water Sampling

Water samples were collected fortnightly in plastic bottles by submerging the bottles into the rivers until they were filled and properly corked. Then, 1 ml each of Manganese Phosphate and Potassium Iodide were introduced into bottles used for collecting samples for dissolved oxygen, (this is to fix the oxygen for analysis). Laboratory analyses were carried out at the Department of Water Resources, Aquaculture, and Fisheries Technology, Federal University of Technology Minna, Nigeria.

Determination of Water Quality Parameters

The temperature of the water was taken *in situ* using a bulb thermometer (100°C range). Dissolved oxygen and BOD were determined using the modified Winkler azide method (Lind, 1979; APHA, 1992). Water pH was determined with a buffer electronic pH meter.

Figure 1. Maps of Nigeria and five sampling stations at Rivers Chanchaga (upstream) and Lapai Gwari (downstream), Minna Niger state, Nigeria

Heavy Metal Analyses

Water samples were digested with 5 ml of HNO_3. Subsequently, the samples were adjusted to a final volume of 50 ml with distilled water. The determination of manganese, iron, copper, and lead (Pb), were done using Atomic Absorption Spectrophotometer (AAS) (Unicam 969).

Data Analysis

One-way ANOVA was used to analyse the water quality parameters and heavy metals concentration from sampled locations. T-test was used to determine the significant difference between the two rivers.

RESULTS

There were variations in the parameters measured from the two rivers. At River Chanchaga, pH ranged from 6.91 to 8.74, dissolved oxygen varied from 4.33 mg/L to 6.93 mg/L, and upstream temperatures increased from 25.33°C to 26.00°C. The biological oxygen demand fell within the range of 0.7 to 1.93 mg/L across sampled locations (Table 1). At River Lapai Gwari, temperature ranged from 24.40°C to 25.00°C. The mean pH increased from 6.90 to 8.47, while dissolved oxygen (DO) varied from 4.33 to 6.93 mg/L (Table 2).

At River Chanchaga, Mn concentrations ranged from 0.04 to 0.13 mg/L, with the highest level observed at Station 2. Iron concentrations ranged from 0.08 to 0.15 mg/L, with the highest concentration occurring at Station 3. Copper varied from 0.02 to 0.03 mg/L, with the maximum recorded at Station 2. Lead concentrations remained consistently low across all stations, with values ranging from 0.00 to 0.01 mg/L (Table 3).

River Lapai Gwari exhibited higher heavy metal concentrations; with Station 1 having significantly higher manganese (0.25 mg/L) and iron (0.37 mg/L) (Table 4). A similar trend was observed at other stations and for copper. However, lead concentrations were relatively low in the two rivers. Copper concentrations showed significant variations between the two rivers. In contrast, manganese concentrations showed significant variability within Chanchaga stations but were not significantly different between the two rivers. Iron concentrations did not differ significantly within and between the two rivers.

Table 1. Water quality parameters at River Chanchaga (upstream), Niger State, Nigeria

Station	Temperature (°C)	pH	Dissolved Oxygen (mg/L)	Biochemical Oxygen Demand (mg/L)
1	26.00±2.00^{a}	7.83±0.77^{a}	5.66±1.01^{ab}	1.13±0.61^{a}
2	25.67±0.58^{a}	7.30±0.42^{bc}	5.93±1.86^{ab}	1.67±1.33^{a}
3	26.00±1.73^{a}	7.14±0.26^{b}	6.93±0.46^{a}	1.93±1.14^{a}
4	25.33±1.53^{a}	6.99±0.19^{c}	5.10±1.02^{ab}	1.56±0.93^{a}
5	26.00±0.00^{a}	6.90±0.08^{c}	5.73±0.81^{ab}	1.06±0.82^{a}

Table 2. Water quality parameters at River Lapai Gwari (downstream), Niger State, Nigeria

Station	Temperature (°C)	pH	Dissolved oxygen (mg/L)	Biochemical oxygen demand (mg/L)
1	25.00±1.73^{a}	8.74±0.89^{abc}	4.53±0.46^{b}	0.93±0.23^{a}
2	24.67±0.58^{a}	8.31±0.69^{ab}	4.86±1.21^{b}	1.67±0.76^{a}
3	24.67±1.16^{a}	7.95±0.75^{abc}	4.33±0.57^{b}	0.73±0.57^{a}
4	24.67±1.16^{a}	7.82±0.96^{abc}	5.00±0.92^{ab}	1.53±0.71^{a}
5	24.67±0.58^{a}	7.81±0.86^{abc}	5.43±1.36^{ab}	1.13±0.31^{a}

Table 3. Heavy metals variations at River Chanchaga (Upstream), Niger State, Nigeria

Stations	Manganese (mg/L)	Iron (mg/L)	Copper (mg/L)	Lead (mg/L)
1	0.04±0.02^{c}	0.09±0.05^{c}	0.02±0.01^{b}	0.00±0.00^{b}
2	0.13±0.03^{b}	0.12±0.08^{c}	0.03±0.02^{b}	0.00±0.01^{b}
3	0.07±0.01^{bc}	0.15±0.03^{c}	0.02±0.01^{b}	0.00±0.00^{b}
4	0.06±0.02^{bc}	0.08±0.03^{c}	0.03±0.02^{b}	0.01±0.01^{b}
5	0.07±0.02^{a}	0.07±0.02^{c}	0.06±0.04^{b}	0.00±0.01^{b}

Table 4. Heavy metals variations River Lapai Gwari (downstream), Niger State, Nigeria

Stations	Manganese (mg/L)	Iron (mg/L)	Copper (mg/L)	Lead (mg/L)
1	0.25±0.04^{a}	0.37±0.06^{a}	0.21±0.17^{a}	0.01±0.01^{b}
2	0.24±0.07^{a}	0.34±0.02^{ab}	0.14±0.06^{ab}	0.01±0.01^{b}
3	0.21±0.06^{a}	0.27±0.04^{b}	0.15±0.13^{ab}	0.02±0.01^{ab}
4	0.26±0.08^{a}	0.33±0.08^{ab}	0.06±0.01^{b}	0.05±0.05^{a}
5	0.24±0.02^{a}	0.31±0.0^{ab}	0.08±0.01^{ab}	0.02±0.01^{ab}

Mean in the same row followed by the same superscript are not significantly different ($P \geq 0.05$)

DISCUSSION

There was a narrow range in temperature variation across sampling stations (24.67°C to 26°C) corroborating the findings of Uko and Tamunobereton-Ari (2013) that no significant differences exists for temperature during the sampled months probably due to close proximity of the rivers (Tables 5 and 6). Previous authors have reported lowest temperatures in August at the upstream and September at the downstream (Idi-Ogede *et al.,* 2016; Ekere *et al.*, 2018). The pH values observed across different months (Table 5 and 6) and stations are similar to the pH levels (6.8 to 8.9) for some tropical rivers (Annalakshmi and Amsath, 2012) and slightly outside the range for inland waters (6.5 - 8.5) (Antoine and Al-Saadi, 1982; Salaudeen, 2016). Nevertheless, the pH falls within the acceptable levels for culturing tropical fish species (Boyd and Lichtkoppler, 1979).

The dissolved oxygen at both the upstream and downstream segments was consistent with the findings of Saxena and Saksena, (2012) who reported DO ranging between 4.40 and 6.95 mg/L and were within the recommended World Health organization rannge of 10 – 12 mg/L.

Biochemical oxygen demand is the amount of oxygen required by the living organisms engaged in the utilization and ultimate destruction or stabilization of water bodies. It also indicates the presence of microbial activities and dead organic matter on which microbes can feed. The findings indicated that both the upstream and downstream segments exhibited biologically clean characteristics, with BOD values ranging from 0.93 mg/L to 1.93 mg/L. It is noteworthy that BOD levels were higher during August, coinciding with the month with the highest rainfall frequency, potentially due to runoff from surrounding areas (Table 5 and 6). Elevated levels of pollutants, such as pesticides, fertilizers, and various nutrients, can lead to an escalation in BOD concentration. This increase is primarily attributed to the consumption of oxygen during the decomposition of organic matter. Consequently, this oxygen depletion negatively impacts the availability of oxygen required by aquatic organisms for their survival (Garg *et al.,* 2006; Karne and Kulkarni, 2009; Verma *et al*., 2012; Kim *et al.*, 2023).

Lead concentrations did not vary significantly between the upstream and downstream segments. However, the highest Pb concentration was detected at station 4 in River Lapai Gwari. Elevated Pb levels are likely attributed to the disposal of household metals and lead-containing paints close to the sampling station. Lead has been classified as a priority pollutant by the United States Environmental Protection Agency (2012) with maximum contaminant level set at 0.015 mg/L whereas the WHO limit is 0.05 mg/L.

Iron had the highest concentrations in July at both locations (Tables 5 and 6), with variations observed in both rivers. Station 1 in the downstream had the highest Fe, possibly due to weathering of rocks around the station. Notably, the recommended limit for iron in water is 0.3 mg/L. Therefore, water from River Lapai Gwari (Stations 1, 2, 4, and 5) exceeded the recommended threshold.

Copper concentrations differed among Stations 1, 2, 3, and 5 in the upstream and downstream segments. Copper concentration can fluctuate due to variations in water pH and hardness (WHO, 2004). The highest monthly variation observed in September at the downstream, might be attributed to elevated runoff. Nevertheless, Cu concentrations fell under the recommended values by the United States Environmental Protection Agency and WHO.

The Manganese concentration varied significant among Stations 1, 2, 3, and 4, possibly as a result of soil erosion, runoff, and weathering. Nevertheless, it did not change significantly over the months. The recommended Mn concentration should not be higher than 0.05 mg/L (Moyosore *et al*., 2014). Hence, Mn concentrations (0.07 to 0.24 mg/L) in the upstream and downstream segments, surpassed the recommended threshold.

CONCLUSION

The physicochemical properties and heavy metal contents in River Chanchaga and River Lapai Gwari were documented. The rivers were suitable for agricultural, domestic, and aquaculture purposes. Most of the physico-chemical parameters and heavy metal concentrations in the upstream (River Chanchaga) fell within the acceptable limits prescribed by WHO (2008) for domestic use and aquaculture. However, in the downstream (River Lapai Gwari), there could be an influx of urban, domestic and agricultural waste, with water quality deterioration being suspected. This is because some of the heavy metals exceeded recommended limits. Hence, strict measures are required to control pollution and influx of wastes.

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Table 5. Monthly variations in heavy metal concentrations and physico-chemical parameters at River Chanchaga (upstream), Minna, Niger State, Nigeria

Parameter	July	August	September
Temperature (°C)	26.80 ±0.84[a]	24.60 ±0.89[b]	26.00 ±0.71[a]
pH	6.86 ±0.05[a]	7.47 ±0.49[a]	7.41 ±0.57[a]
Dissolved oxygen(mg/L)	6.50 ±0.79[a]	5.12 ±1.06a	6.00 ±1.24[a]
Biochemical oxygen demand (mg/L)	1.30 ±1.15[a]	1.88 ±0.92a	1.24 ±0.62[a]
Manganese (mg/L)	0.08 ±0.02[a]	0.08 ±0.03[a]	0.07 ±0.05[a]
Iron (mg/L)	0.12 ±0.04[a]	0.10 ±0.04[a]	0.08 ±0.06[a]
Copper (mg/L)	0.03 ±0.01[a]	0.04 ±0.03[a]	0.03 ±0.02[a]
Lead (mg/L)	1.60 ±0.89[a]	1.60 ±0.89[a]	1.60 ±0.89[a]

Mean in the same row followed by the same superscript are not significantly different ($P \geq 0.05$)

Table 6. Monthly variations in heavy metal concentrations and physico-chemical parameters at River Lapai Gwari (downstream), Minna, Niger State, Nigeria

Parameter	July	August	September
Temperature (°C)	24.60 ±0.89[a]	25.20 ±1.30 [a]	24.40 ±0.55 [a]
pH	7.88 ±0.08[b]	8.97 ±0.41[a]	7.52 ±0.79[b]
Dissolved oxygen(mg/L)	5.76 ±0.89[a]	4.12 ±0.44[b]	4.62 ±0.39[b]
Biochemical oxygen demand (mg/L)	1.28 ±0.50[a]	0.88 ±0.44[a]	1.44 ±0.77[a]
Manganese (mg/L)	0.24 ±0.06[a]	0.23 ±0.05[a]	0.24 ±0.06[a]
Iron (mg/L)	0.36 ±0.06[a]	0.28 ±0.04[b]	0.33 ±0.05[ab]
Copper (mg/L)	0.08 ±0.02[a]	0.09 ±0.03[a]	0.21 ±0.15[a]
Lead (mg/L)	0.02 ±0.01[a]	0.02 ±0.01[a]	0.03 ±0.04[a]

Mean in the same row followed by the same superscript are not significantly different

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